Application of a Spectrally Consistent Multichannel Adiabatic Retrieval to the MODIS Cloud Product

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Background

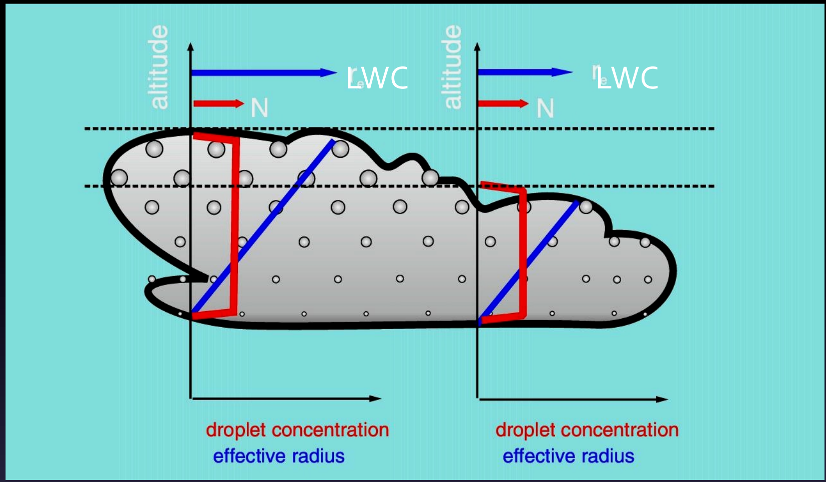
Our goal is to investigate the utility and efficacy of a cloud retrieval which takes advantage of MODIS' plurality of liquid water absorption channels to better estimate cloud droplet number concentration and geometrical thickness in boundary layer clouds.

Additionally, by exploiting the differing penetration depths of the various channels perhaps we can gain some insight into the vertical structure of these clouds.

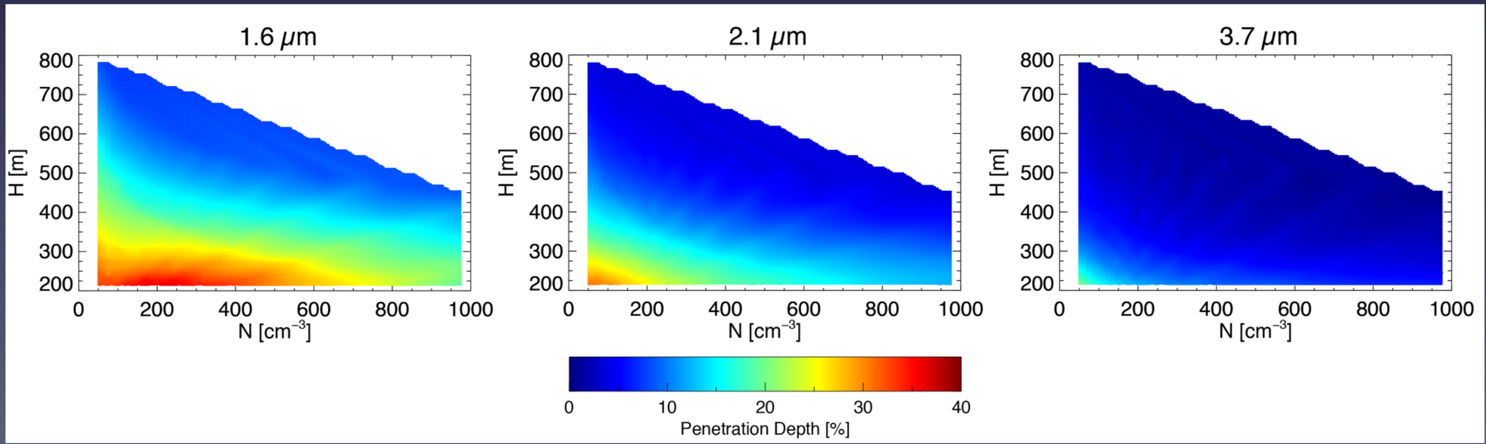
Background

Adiabatically stratified cloud:

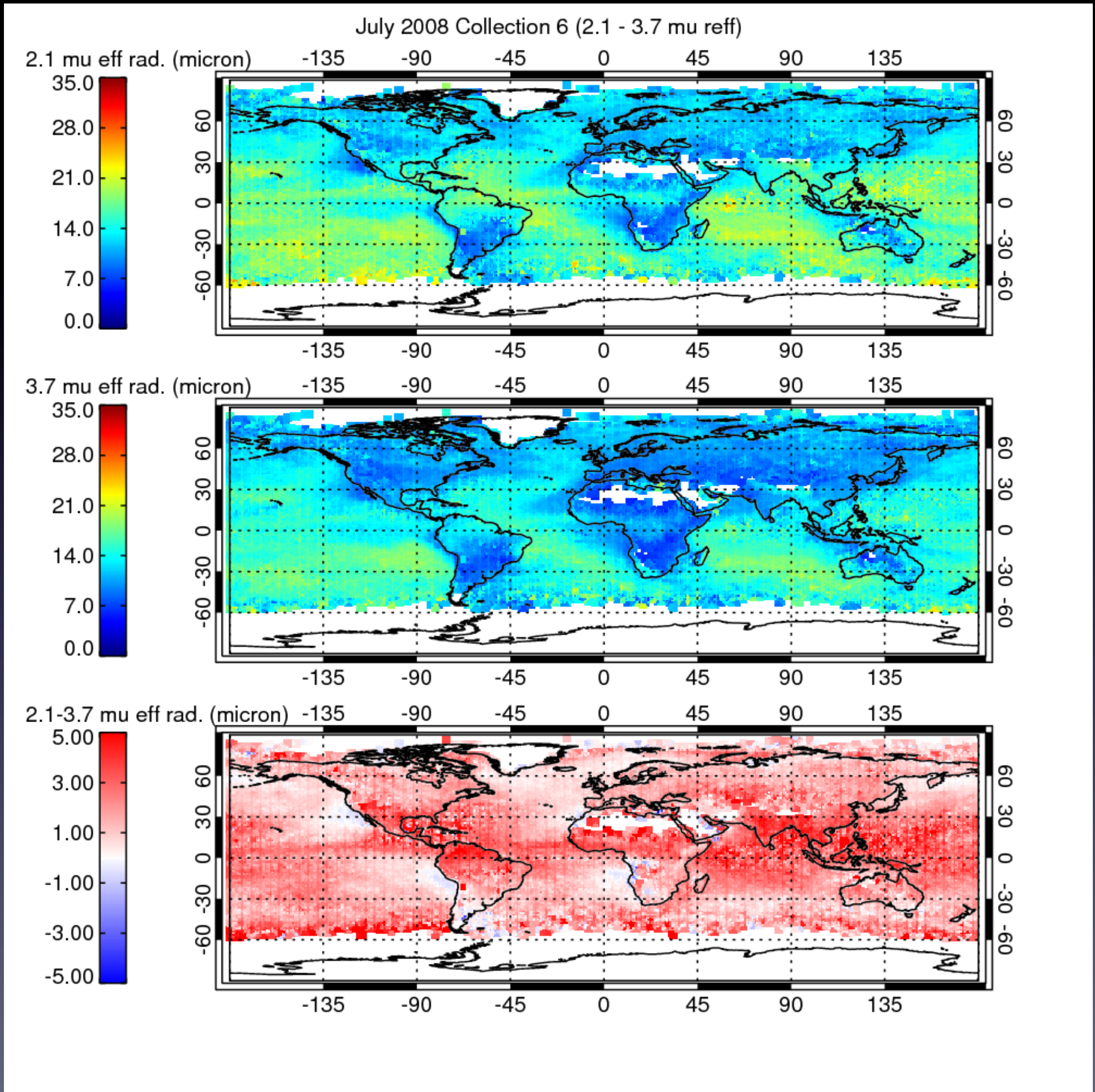
Cloud liquid water content increases linearly with height (moist adiabatic ascent). This provides a constraint on the cloud vertical profile.



Penetration depth: Where does retrieved effective radius match profile effective radius?



Effective Radius



Background

- Platnick (2000) addressed the retrieval depth issue through modification of absorption channel weighting functions for MODIS
- Chang and Li (2003) modified attempted to derive vertical profile by differencing 1.6, 2.1 and 3.7 micron retrievals.
- retrievals. Cast in terms in a vertically uniform model.
- Precipitation signature? Suzuki, Nakajima, Stephens 2010, 2011
- Cloud inhomogeneity? Zhang, Platnick 2011

Motivation for SCAR retrieval

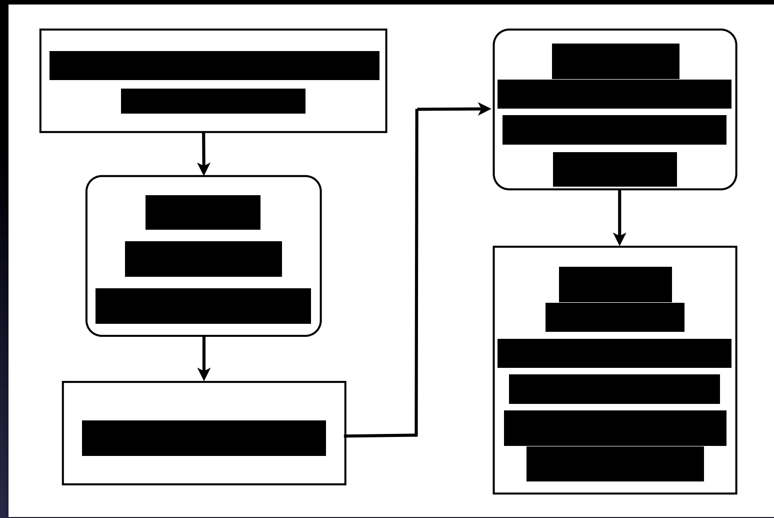
- The adiabatically stratified liquid water profile is arguably more representative of cloud vertical structure than the vertically uniform profile.
- Cloud droplet number concentration (*N*) and geometrical thickness (*H*) lend themselves as superior coordinates to optical thickness and effective radius in an near-adiabatic cloud (Brenguier et al., 2000; Schuller et al. 2003).
- The VU Nakajima and King (1990) retrieval used in the MODIS cloud product, does not lend itself directly to this endeavor requiring some additional work to recast it in AD coordinates.

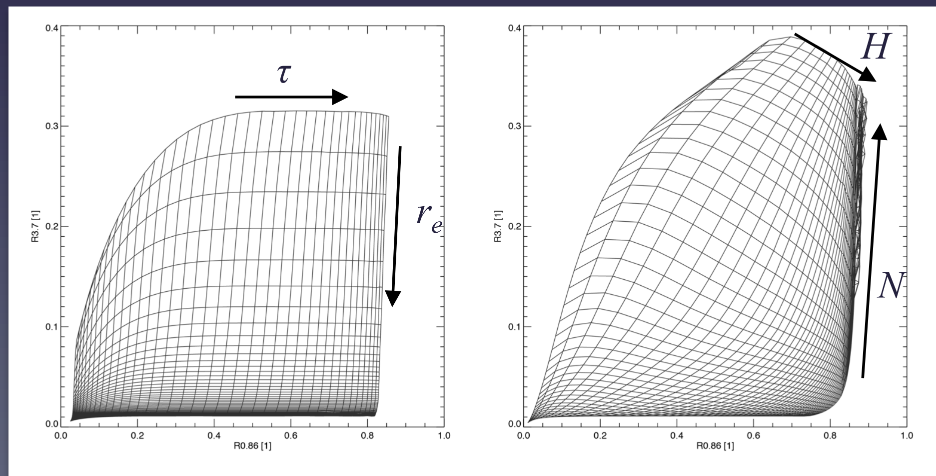
A Spectrally Consistent Adiabatic Retrieval

- Take existing VU-PPM MODIS retrievals of optical thickness and effective radius values and invert them to obtain scene reflectances at 0.86,1.6,2.1,3.7 μm referencing a VH LUT.

- From all four reflectances, obtain a Spectrally Consistent Adiabatic Retrieval (SCAR) of droplet number concentration (*N*) and geometrical thickness (*H*) from AD LUTs through optimal estimation.

- In total we have 4 estimates of *N* and *H*. One from each of the three absorption channels and one using all channels simultaneously.



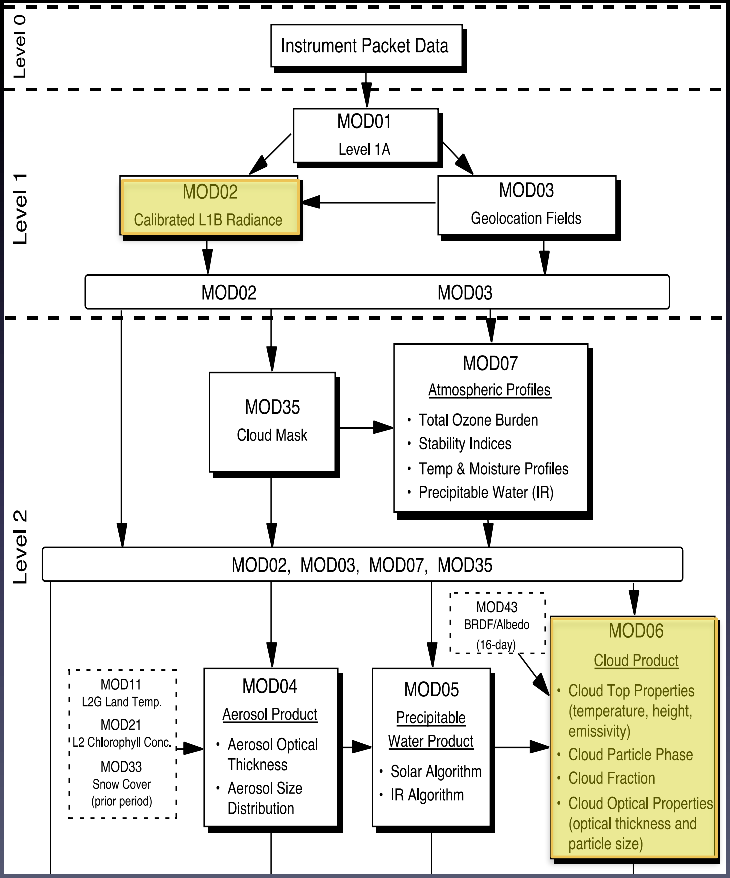


Why invert the cloud product?

In principle, this technique could also use the Level 1B radiances (MOD02 Product) as inputs.

However, the existing cloud product has a significant amount of quality control work applied in addition to surface, atmospheric and retrieval geometry corrections.

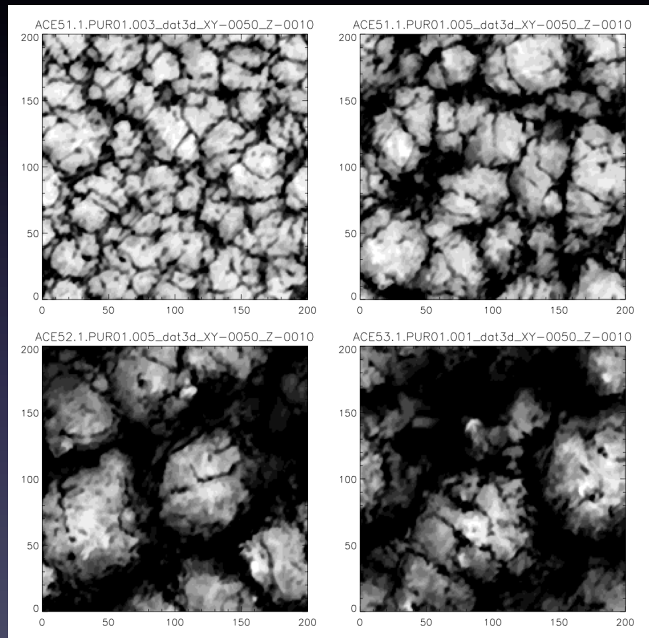
For purposes of proof of concept, using the existing cloud product makes this problem more tractable.



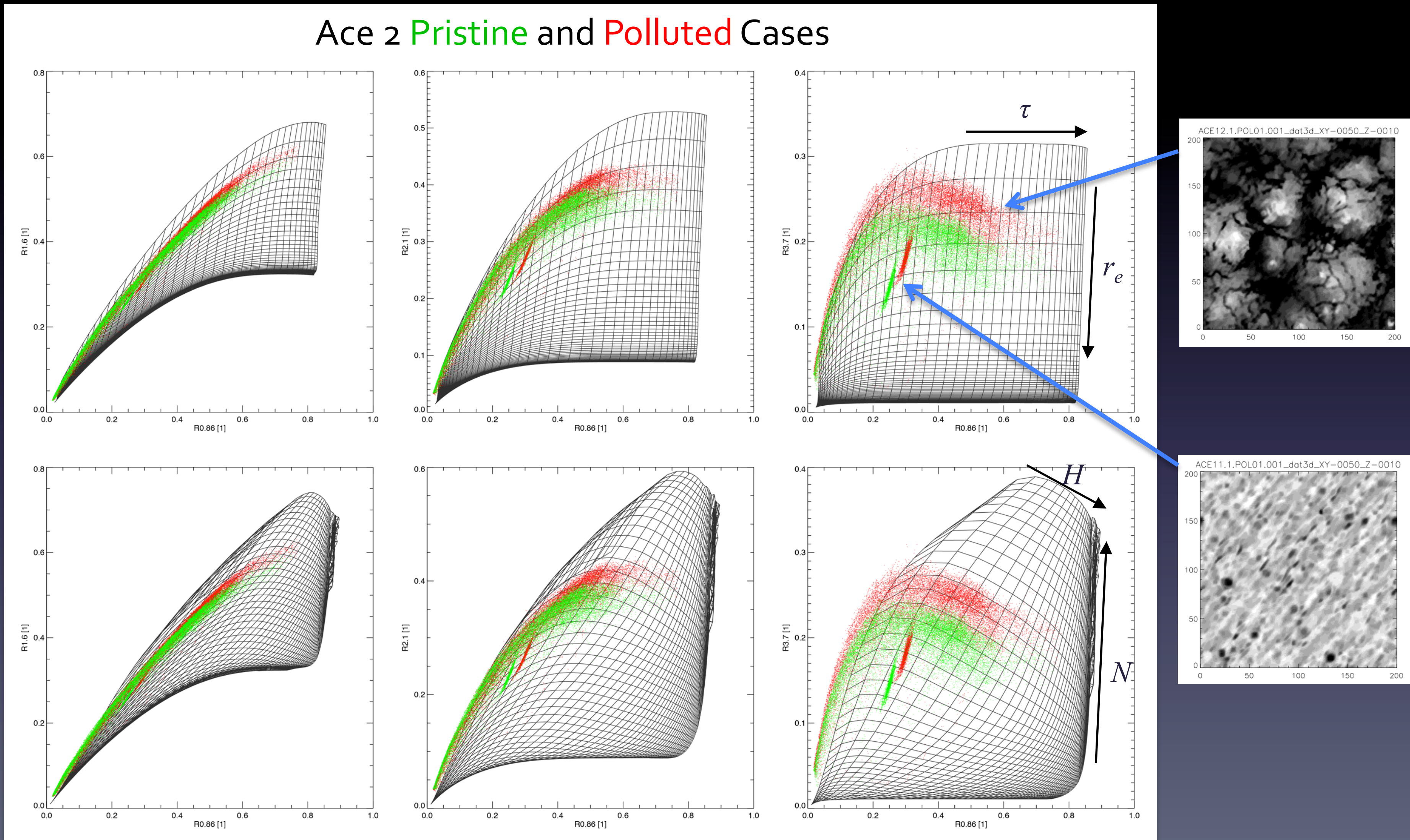
MODIS ATBD (King et al., 1997)

Application to LES

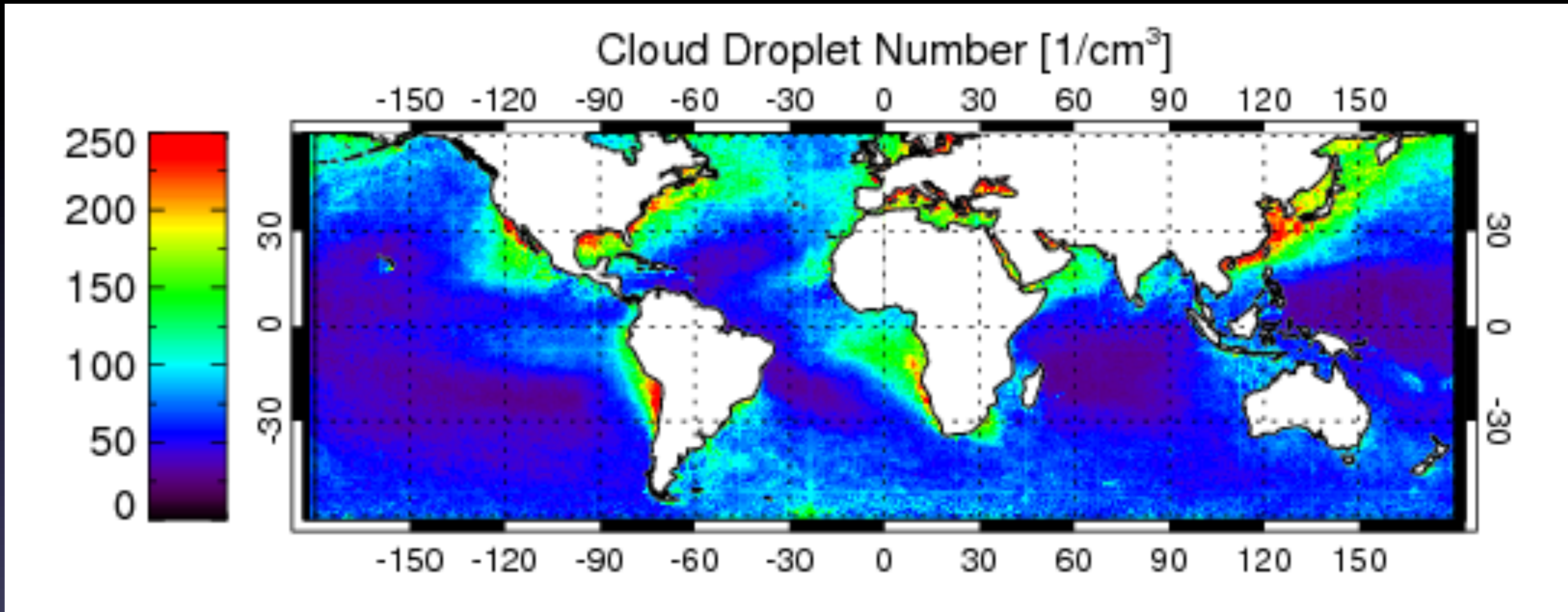
- LES cloud fields offer an opportunity to “test-drive” SCAR for various cloud cases with differing vertical structure.
- The SCAR method was applied to 72 large eddy simulations of cloud fields observed during the ACE2 and FIRE field campaigns.
- Each field has a high CDNC “polluted” and low CDNC “pristine” case.



Application to LES



Cloud droplet number concentration



Quality Metrics

- Since direct measurement of the profile is not an option, we are left to infer.
- RMS difference, *Q* between retrievals of *N* or *H* may provide some insight.

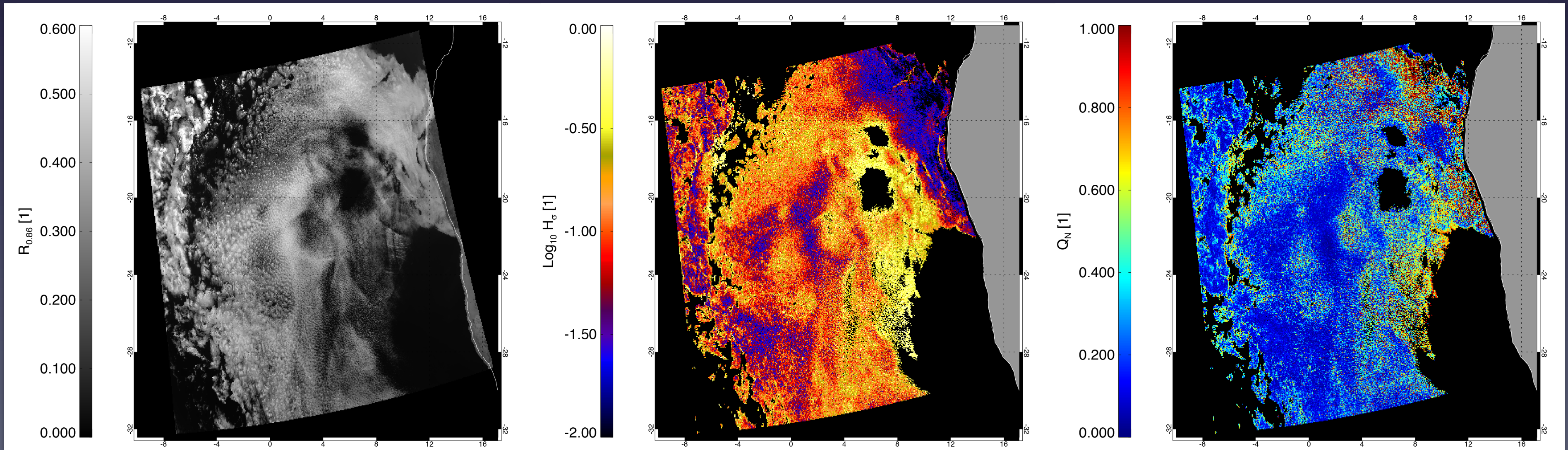
$$Q_N = \frac{1}{N_{AD}} \frac{\sqrt{(N_{AD} - N_{1.6})^2 + (N_{AD} - N_{2.1})^2 + (N_{AD} - N_{3.7})^2}}{3}$$

- Heterogeneity Parameter :

  H_σ = StdDev(R[0.86μm , 250m])/Mean(R[0.86μm,250m]), (Liang, et al. 2009) is applied as reference proxy for variation in vertical profile.

Application to the cloud product

- Q_N appears to be a superior metric over Q_H due to the greater dynamic range of *N* in LUTs relative to *H*, yielding higher sensitivity.
- Applying SCAR and comparing Q_N to heterogeneity index yields a visual correlation between parameters.
- Despite the visual correlation, on average $R(H_\sigma, Q_N) = 0.43$ over 303 granules



Conclusions

- The SCAR method produces a retrieval that better conforms with true vertical structure of cloud by virtue of additional constraints provided by adiabatic framework.

- It can also fall victim to the same pitfalls experienced in conventional retrievals (3D effects, multiple scattering or poor S/N ratio for some channels, etc.)

- Vertical structure proxy is subject to significant natural variability and noise for actual observations

References

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